SMART AND RESILIENT CITIES

A SYSTEMIC APPROACH FOR DEVELOPING CROSS-SECTORAL STRATEGIES IN THE FACE OF CLIMATE CHANGE

ROCCO PAPA[A], ADRIANA GALDERISI[A], MARIA CRISTINA VIGO MAJELLO[A], ERIKA SARETTA[A]

[A] University Federico II of Naples, Department of Civil, Architectural and Environmental Engineering, Naples, Italy

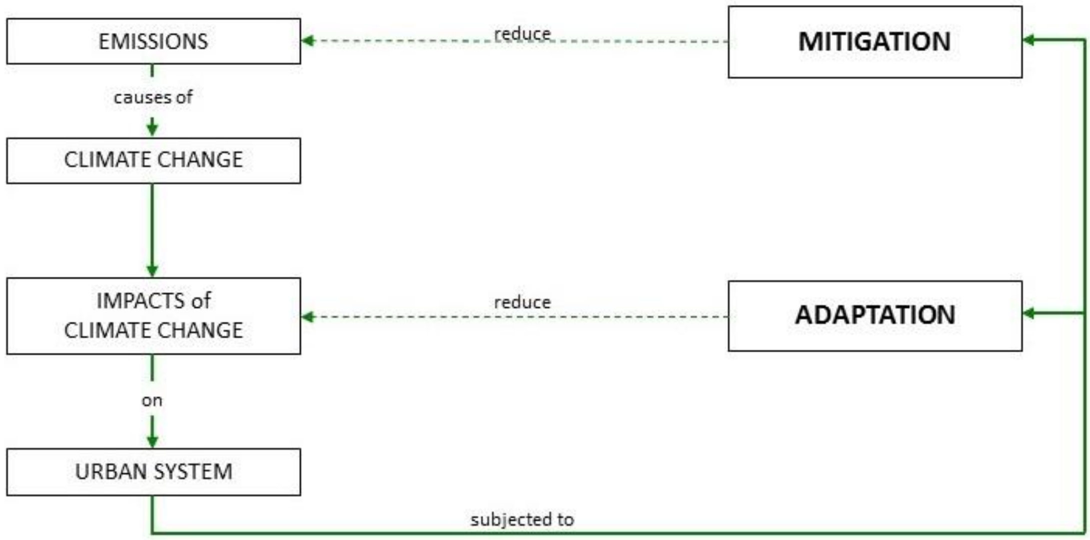
ABSTRACT

Climate change is considered one of the main environmental issues challenging contemporary cities. Meanwhile, urban development patterns and the growth of urban population represent the main contributors to climate change, affecting the total energy consumptions and the related greenhouse gas emissions. Therefore, a breakthrough in current urban development patterns is required to counterbalance the climate-related issues.

This study focuses on the Smart City and Resilient City concepts; in detail, based on the review of existing literature, it analyzes the synergies between the two concepts, highlighting how the Smart City concept is more and more widely interpreted as a process addressed to make cities "more livable and resilient and, hence, able to respond quicker to new challenges" (Kunzmann, 2014). Nevertheless, current initiatives to improve cities' smartness and resilience in the European cities are very fragmented and operational tools capable to support multi-objective strategies are still at an early stage. To fill this gap, embracing a systemic perspective, main characteristics of a smart and resilient urban system have been identified and arranged into a conceptual model. The latter represents a preliminary step for guiding planners and decision-makers towards the development of multi-objective strategies capable to improve the response capacities of complex urban systems in the face of climate change. Then, in order to better understand whether and how such a model may contribute to frame and guide current mitigation and adaptation strategies, the emblematic case study of Rotterdam has been in-depth analyzed.

Keywords: Smart City, Resilient City, Systemic approach, Climate Change, Climate Adaptation.

According to the available trends and projections (UN, 2014), urban population has overcome the rural one since 2005 and it is expected to further increase by 2050. Even though cities represent only the 4% of the Earth's land (UNEP, 2014), they consume about the 67% of the global primary energy (IPCC, 2014) and, due to urban lifestyle and economy, they are responsible for more than the 70% of greenhouse gas (GHG) emissions (Birkmann et al. 2010; EU, 2011) that are, in turn, the main contributors to climate change. Thus, according to current trends, the expected growth of urban population will further increase energy consumptions, worsening the current energy scenario. Moreover, the "continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system" (IPCC, 2013), with effects that will be particularly severe in urban areas, due both to the concentration of people, assets and strategic activities and to the peculiarities of cities that may exacerbate the impacts of the heterogeneous



climate-related phenomena.

Fig. 1 - Relations between urban system, climate changes, mitigation and adaptation (elaborated by Füssel et al., 2006).

Fortunately, cities can be interpreted as "cauldrons of diversity and differences and as fonts for creativity and innovation" (Florida, 2003): therefore, although playing a major role in the creation of current environmental challenges, they can be considered as a central part of any response.

Thus, mitigation strategies, addressed to reduce energy consumptions, combined with adaptation strategies, aimed at counterbalancing climate-related impacts, represent crucial challenges that cities have to deal with, in order to guarantee a sustainable urban environment for the rapidly growing urban population. Indeed, on the one hand, mitigation actions can allow the reduction of CO_2 emissions and, consequently, of climate-related impacts on urban areas. On the other hand, adaptation actions can enhance urban capacities to cope with unavoidable impacts of climate change (fig.1).

The issues related to the reduction of energy consumptions and to the urban adaptation to climate change have been considered as crucial in most of the recent metaphors related to urban development and addressed to improve cities capacities to cope with urgent environmental challenges (Moir et al., 2014): eco-cities, low-carbon cities, transition cities, smart cities, resilient cities represent only some examples.

We will focus here on the metaphors of "smart" and "resilient" cities, which seem to play a leading role due both to the growing attention paid by scholars all around the world to these terms and to the increasing number of on-going initiatives both on the global and on the European scale.

In detail, according to some scholars, 40 global cities will become smart by the year 2020 (EIP, 2014) and by 2025 the number of Smart City all around the globe will climb from 21 of the 2013 up to 88 (Smart City Council, 2014a). Moreover, the European Commission has launched the European Innovation Partnership for

Smart Cities and Communities for supporting "energy production, distribution and use; mobility and transport; and information and communication technologies (ICT)" to "improve services while reducing energy and resource consumption and greenhouse gas emissions" (EIP, 2013). Meanwhile, about 2100 cities all over the world have joined the "Making Cities Resilient" Initiative, launched in 2010 (UNISDR, 2012a) and, in December 2014, 100 cities have been selected by the Rockefeller Foundation Initiative for the "100 Resilient Cities Challenge" (Rockefeller Foundation, 2015). In Europe, a strategy addressed to enhance cities' adaptation to climate change in order to realize a "more climate-resilient Europe" has been established (EU, 2013) and the "LIFE+ Program" focused on urban resilience (EU LIFE, 2014) has been launched.

Despite the numerous on-going initiatives, both Smart City and Resilient City are still vague and fuzzy concepts. In the case of the Smart City, about 30 definitions have been proposed since 2000 (Caragliu et al., 2009). In current literature a Smart City is generally characterized by the wide use of Information and Communication Technologies (ICTs) for traditional infrastructures as well as for improving the active participation of human and social capital (Caragliu et al., 2009; Toppeta, 2010; Dameri, 2013). Such technology-based approach is often considered capable of dealing with different urban problems (Batty et al., 2012; Lee et al., 2013), guaranteeing both the quality of the urban environment and the sustainability of its development. On the opposite, it is worth noting that not many definitions of Resilient City have been provided even though the concept of resilience – developed since the Seventies – seems to be particularly suitable for urban areas (Galderisi, 2014). Focusing on the resilience concept, some authors emphasize that resilience is "in danger of becoming a vacuous buzzword from overuse and ambiguity" (Rose, 2007), "increasingly viewed in a rather vague and malleable meaning" (Brand and Jax, 2007). Notwithstanding, some organizations agree on a definition of a Resilient City as a city capable to withstand or absorb the impact of hazards, shocks and stresses through adaptation or transformation, in order to guarantee a long-term sustainability, as well as its basic functions, characteristics and structures (UNISDR, 2012b; ICLEI, 2014a; Resilient City, 2014).

Thus, based on the review of existing literature and embracing a systemic perspective, this contribution will highlight synergies and mismatches between the two concepts, identifying the main characteristics of a smart and resilient urban system and arranging them into a conceptual model. Such a model should guide planners and decision-makers towards the development of multi-objective strategies, capable to improve the response capacities of complex urban systems in the face of climate change. The case study of Rotterdam – currently striving for integrating smart and resilient initiatives as well as mitigation and adaptation strategies – will be in-depth analyzed, in order to highlight whether and how current initiatives effectively contribute to strengthen the above mentioned capacities, building up smarter and more resilient cities.

This study represents a first step for shifting from current "silo" approaches - based on the fragmentation of knowledge, strategies and responsibilities (EEA, 2014) - towards a systemic one, capable to support cross-sectoral strategies and multi-objective actions, more and more crucial in the face of current economic crisis, for enhancing the capacities of complex urban systems to deal with more and more interconnected challenges.

1. COMPARING SMART AND RESILIENT CITY'S CONCEPTS

1.1 SMART AND RESILIENT CITIES: TOWARDS NEW PARADIGMS?

Currently, Smart City and Resilient City are drawing an increasing attention by urban planners, decision-makers and municipalities, as shown by the proliferation of academic researches, as well as of institutional initiatives on these topics. Thus, Smart City and Resilient City are becoming widespread labels, despite the lack of shared definitions.

Approaching the terms, the first issue arising refers to their definition as concept or paradigms: some scholars indeed refer to the Smart City as a paradigm (Auge et al. Blùm, 2012; New City Foundation, 2014; Bencardino and Greco, 2014), while others consider it as a concept (Washburn, 2011; Cretu, 2012; Dameri, 2013; BSI, 2013; EIP, 2013). It is worth noting that also halfway positions exist, looking at the Smart City as an emerging paradigm (Kunzmann, 2014). The Resilient City is a recent term based on resilience that some scholars define as a concept (Rose, 2007; Davoudi, 2012) or even as a "new umbrella concept", able to take into account "risk management, ecological, sustainability or political sciences" (Chelleri, 2012), while others as a paradigm (Ercoskun, 2012; Rogers et al., 2012).
It has to be underlined that a paradigm can be defined as a "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners" (Kuhn, 1970); whereas a scientific concept is generally represented through three parts: a label, a theoretical definition that permits "others to understand our theory and be able to criticize and reproduce our observations" and an operational definition that "translates the verbal meaning provided by the theoretical definition into a prescription for measurement" (Suppe, 1997).
Hence, due both to the lack of a shared scientific definition of the two terms and to the heterogeneity of city programs and initiatives addressed to improve urban smartness and/or resilience, it seems hard to define them as paradigms: both Smart City and Resilient City contribute in offering solutions and opportunities for urban problems but, so far, they do not represent a "universally recognized scientific achievements". On the opposite, they can easily considered as concepts: both of them are more and more used as urban labels (Hollands, 2008; Caragliu et al., 2009; Davoudi, 2012), numerous definitions of each term are currently available and, even though their operational definition is still at an early stage, some basic elements have been developed, such as domains (for the Smart City concept), characteristics and indicators.
Thus, according to such interpretation, definitions, evolution paths and goals of the two concepts will be reviewed and compared, highlighting their synergies and mismatches, as a starting point to develop an integrated operational approach to Smart City and Resilient City.

1.2 DEFINITIONS

The Smart City concept has gained an increasing attention in the last decade by scholars, practitioners and decision-makers, even though "a clear-cut, common definition of smart cities is still lacking" (Moser et al., 2014).
The growing attention paid to this concept since the 2000 is clearly highlighted by the search query data from Google Trends (fig. 2): the search engine Google, indeed, provides access to information on the volume of queries for different search terms as well as on the change over time of these volumes, through the publicly available service Google Trends.
Studies and researches on Smart City developed in the last years, arising from different disciplinary fields and perspectives (academic, industrial, institutional) and focusing on different topics, have led to a number of heterogeneous definitions. Some of them focuses on environmental issues, paying large attention to the efficient use of natural resources and to energy consumptions (EIP, 2013; Karnouskos et al., 2013, Kramers et al., 2014); others on socio-economic issues, highlighting the importance of social and human capital (Moser, 2001; Florida, 2003; Partridge, 2004; Glaeser and Berry, 2006; Giffinger et al., 2007; Dirks et al., 2010); others on institutional aspects, emphasizing the potential of ICTs in improving current decision-making processes and supporting the empowerment of local communities (Coe et al., 2001; Eger, 2009; Paskaleva, 2009)
Nevertheless, although the large variety of studies and researches focuses on different aspects, they agree on the crucial role of ICTs (Mosannenzadeh and Vettorato, 2014), assigning to technology different weights, according to the different disciplinary perspectives.

Summing up, the many definitions of Smart City currently available bring out a variety of approaches and interpretations of the concept, although this multiplicity can be effectively reduced to two broad categories:

- a first one comprises the definitions referred to a "technology-based" approach, mainly focused on urban physical infrastructures (e.g., Hall, 2000; STERIA, 2011; Lazaroiu and Roscia, 2012; Aoun, 2013)
- a second one includes the definitions based on a holistic approach to the Smart City, capable to take into account the numerous and interconnected components that characterize an urban system (e.g., Giffinger et al., 2007; Nam and Pardo, 2011; Lee et al., 2013; Papa et al., 2013).

Among the numerous collected and analyzed definitions (approximately 30), the most relevant ones have been then selected (Tab. 1), based on the number of quotations of the article comprising such definitions reported by Google Scholars. It is worth noting that all the selected definitions, which represent the most cited ones, are all referred to the second category.

Fig. 2. Google Trends for "Smart City"

REFERENCE	DEFINITION	CITATIONS
Caragliu et al. 2009	We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.	358
Komninos N. et al., 2011	The Smart Cities concept (...) is connected to notions of global competiveness, sustainability, empowerment and quality of life, enabled by broadband networks and modern ICTs.	291
Giffinger R. et al., 2007	A Smart City is a city well performing in a forward-looking way in these six characteristics, built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens.	207
Nam T., Pardo T.A., 2009	Smart city integrates technologies, systems, infrastructures, services, and capabilities into an organic network that is sufficiently complex for unexpected emergent properties to develop.	103
Odendaal N., 2003	A smart city or region (...) is one that capitalizes on the opportunities presented by Information and Communication Technology (ICT) in promoting its prosperity and influence.	93
Batty M. et al., 2012	Smart city as city in which ICT is merged with traditional infrastructures, coordinated and integrated using new digital technologies. Smart cities are also instruments for improving competitiveness in such a way that	87

	community and quality of life are enhanced

Tab. 1. Smart City Definitions

According to some scholars (Moir et al., 2014), also the "Resilient Cities is a concept growing in use". The term appeared in 2002 in the "Resilient Communities Program Concept" and in 2004 it was used as a "*metaphor (…) to help link ecology and planning*" (Pickett et al., 2004). The term was largely widespread thanks to the book edited by Vale and Campanella (2005) and titled "The Resilient City". The volume focused on the persistence of cities in the face of disasters and namely on their capacity to "rebound from destruction", being the cities "among humankind's most durable artifacts". Nevertheless, only recently the term "Resilient City" is gaining importance in the scientific debate: the Google Trends (Fig. 3) highlight that the term enters the search queries starting from 2012, after the Sandy Hurricane that caused about 19 billion dollars of total damage. The human and economic loss due to such event probably pushed national and local governments towards the adoption of strategies and initiatives aiming at enhancing urban resilience in the face of climate-related events, thereby promoting studies and research on this issue.

Also for the Resilient City concept, heterogeneous definitions are available; some of them have been provided by scholars (Newman et al., 2009; Fusco Girard et al., 2012), others by institutions (UNISDR, 2012a), large international organizations (World Bank Group, 2011)or private foundations (Rockefeller Foundation, 2015). Nevertheless, all the available definitions agree on the main idea that a resilient city is a city capable to absorb external pressures or to adapt or transform in front of such pressures, guaranteeing the safety of settled communities and the preservation of its basic functions during a crisis.

Referring to the same temporal span, it is worth noting that the total number of definitions of the term Resilient City that can be found in current literature is by far lower than those available for Smart City. The most quoted definitions or the most widespread on the international level are shown in Table 2. Nevertheless, it has to be underlined that despite the definitions of Resilient City are fewer than those related to the Smart City, this concept roots in the wide research field focused on resilience, and namely on the resilience of social-ecological systems (Adger et al., 2005; Folke, 2006; Brand and Jax, 2007), to which a growing attention has been paid since the 2000 (Fig. 4). Numerous studies and researches have been carried in the last decades on the resilience of socio-ecological systems in the face of heterogeneous pressure factors, such as:

- natural hazards/climate change (e.g., Sapountzaki, 2010; Bahadur et al. , 2010; Jabareen, 2013; IPCC, 2013; Galderisi, 2014);
- energy consumptions and oil dependency (e.g., Newman et al., 2009; Hopkins, 2008; North, 2010);
- economy (e.g., Rose, 2007; Drobniak, 2010; Simmie and Martin, 2010).

However, here we will refer only to the definitions of Resilient City, purposely neglecting the numerous and heterogeneous definitions of resilience, in order to allow a more immediate comparison with the Smart City definitions.

Fig. 3. Google Trends for "Resilient City"

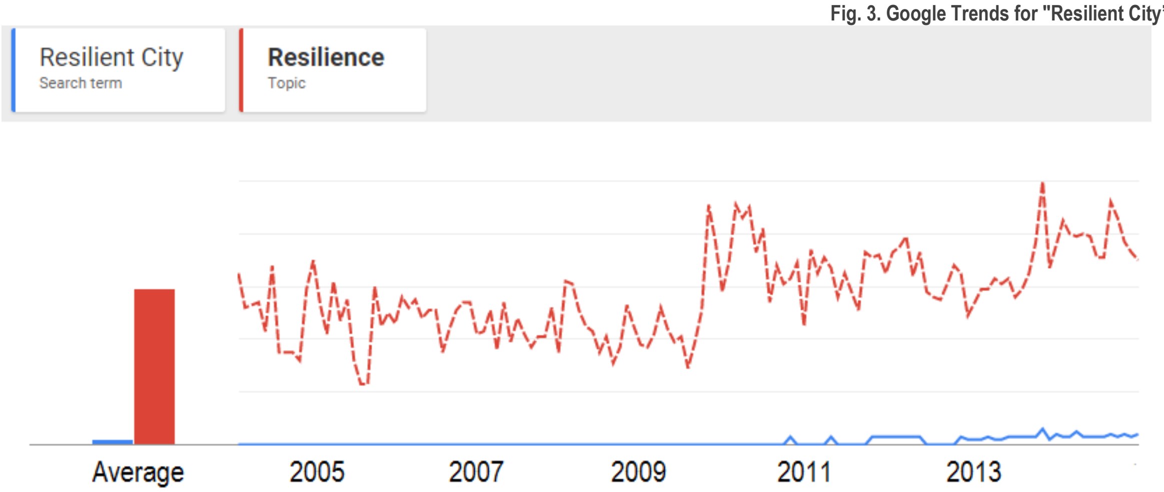


Fig. 4. Google Trends for "Resilience" (blue) and for "Resilient City" (red)

REFERENCE	DEFINITION	CITATIONS
Newman et al., 2009	We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.	358
Nijkamp P. et al., 2012	The Smart Cities concept (…) is connected to notions of global competiveness, sustainability, empowerment and quality of life, enabled by broadband networks and modern ICTs.	291
Resilient Communities Program Concept, 2002	A Smart City is a city well performing in a forward-looking way in these six characteristics, built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens.	207
UNISDR, 2012	Smart city integrates technologies, systems, infrastructures, services, and capabilities into an organic network that is sufficiently complex for unexpected emergent properties to develop.	103

Table 2. Resilient City Definitions

Similarly to the case of Smart City, even in the most commonly used definitions of Resilient City there is a tendency to take into account different disciplinary perspectives, considering social, economic and

environmental factors and their interrelationships as a key for an effective understanding of the complexity of urban systems and namely of their behaviors in the face of heterogeneous pressures.
Briefly, according to the proposed definitions, the Smart City is a widespread label underlying a vision of the city based on the potential of ICTs as a key tool "to fuel sustainable economic growth and a high quality of life" (Caragliu et al., 2009). The Resilient City promotes a vision of the city in which efforts are addressed to increase the ability of the city to respond to heterogeneous pressure factors (climate, environmental, energy and economic), with the ultimate aim of ensuring a higher quality of life and sustainable urban development.
Furthermore, numerous scholars point out that ICTs, key tools for increasing urban smartness, could play a significant role also in reducing urban vulnerability and improving cities' resilience. According to Heeks et al. (2013), indeed, "ICTs can help strengthen the physical preparedness of communities by helping those communities to optimize the location of physical defenses" and "can also strengthen institutions needed for the system to withstand the occurrence of climatic events".
Summing up, the analysis and the comparison among the definitions of Smart City and Resilient City highlight important commonalities between the two concepts, even though the lack of clear-cut common definitions and the fact that both concepts are still evolving make a conclusion still open and harbinger of future research developments.

1.3 CONCEPTS' EVOLUTION

In the previous paragraph, the definitions of the Smart City and of the Resilient City have been compared with reference to a time span ranging from the 2000 to the 2014. However, the considered definitions already refer to an end-point, although not a final one, of an evolutionary process that is far more temporally extended since the roots of each concept, can be traced in research works carried out some decades ago. Hence, to better understand current similarities and/or differences among the two concepts of Smart and Resilient City, the evolution path of each concept will be sketched, highlighting the variety of contributions arising from different disciplinary fields that contributed to building up their current meanings.
In respect to the Smart City, it is worth reminding that the term "smart" has been primarily used in the Nineties by the Smart Growth American movement, which "refers to policies for the management of growth of urban and suburban settlement and to a set of principles for designing". Moreover, the Smart Growth also refers to "an idea of the city" capable to "provide an alternative to sprawl" (Pellegrini, 2003). The movement, mainly referred to the development of new residential areas, was addressed to reduce soil consumption and sealing, promoting more sustainable developments (Moccia, 2012).
Nevertheless, the main roots of the term Smart City as it is currently interpreted "have to be traced in some of the phenomena that characterized the Eighties and the Nineties, namely, in the evolution and diffusion of ICT and in their outcomes in terms of globalization of economy and markets" (ABB-Ambrosetti, 2012; Papa et al., 2013). The term Smart City was coined at the beginning of the Nineties in order to point out an urban development more and more dependent on technology and on innovation and globalization phenomena, mainly by an economic perspective (Gibson, Kozmetsky and Smilor, 1992).
Thus, since the Nineties ICT represented a key tool for increasing efficiency, attractiveness and competitiveness of cities. Starting from the early 2000s, large industries such as Cisco, Ericsson, IBM have significantly invested in the integration of ICTs within cities, strongly supporting the spread of a techno-centered approach to the Smart City concept. Nevertheless, in the mid of the 2000s a human-centered approach, focused on the key role of the human and social capital as starting levers for a "smart" urban development, began to take shape. In the second half of the 2000s, thanks to the study of Giffinger et al. (2007), the Smart City concept gained larger room in the scientific debate. Giffinger et al. (2007) provided a model of Smart City, interpreted as "a city well performing in 6 characteristics, built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens" and a method for measuring and comparing urban smartness. The six characteristics - or, better, the sectors in which a

Smart City has to ensure high performances - can be identified as follows: smart economy; smart people; smart governance; smart mobility; smart environment; smart living.

Hence, this study paved the way to an integrated approach to the Smart City concept and, based on this numerous scholars have recently provided an interpretation of the smart city as a city in which ICTs are addressed to improve the overall urban performances and, above all, the quality of life of citizens. Among them, the research work carried out by Caragliu et al., (2009), focused on the relationships among technological and social aspects, intellectual capital, health and governance issues, and the studies of Mark Deakin (2012), who proposed the model of the "Triple Helix" for promoting social innovation, stressing on the close relationships between sustainable development and Smart City.

As a result, recently "a broader conceptualization of Smart Cities places emphasis on good city governance, empowered city leaders, smart or 'intelligent citizens' and investors in tandem with the right technology platform" (Moir et al., 2014), supporting strategies addressed to improve both "hard" (infrastructures, ICTs, etc.) and "soft" urban components (human and social capital).

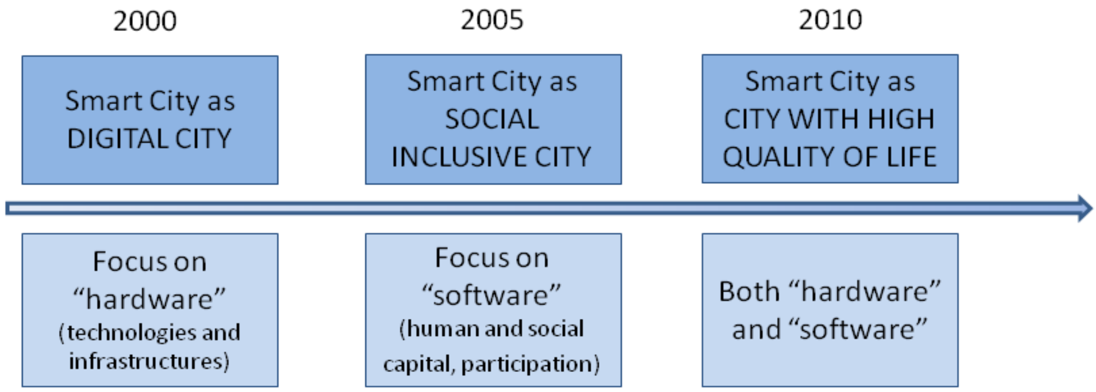


Fig. 5. Evolution of the Smart City concept

As mentioned above, the term "Resilient City" gained large attention by institutions, policy makers and scholars after the Hurricane Sandy that, in 2012, hit the North Eastern part of the USA and the city of New York, causing 43 deaths and economic damage for about 19 billion dollars. In the last years, the constantly increasing popularity of the concept is mainly due to its widespread use and promotion by international organizations (eg. the UNISDR that in 2010 launched the Making Cities Resilient campaign, addressed to involve local Authorities and enhance urban resilience in the face of natural and man-made hazards); private organizations (eg. the Rockefeller Foundation, which identifies specific "challenges" that cities have to deal with - from natural hazards to social issues – promoting the initiative "100 Resilient Cities") and associations of cities and local governments (eg, ICLEI that deals with urban resilience against climate-related impacts).

Although the concept of Resilient City has recently come to the fore, the studies on resilience have been developed since the Fifties through different disciplinary fields, from physics to psychology, from ecology to management science. Referring to previous research works for an exhaustive description of the evolution path of the resilience concept (Martin-Breen and Anderies, 2011; Alexander, 2013; Galderisi, 2014), we will here point out some milestones along this path. Resilience found large room in Ecology during the Seventies, thanks to Holling (1973) that firstly focused on the behavior of natural systems in the face of external perturbations. In the mid of the Nineties, Holling provided a clear distinction between an engineering and an ecological approach to resilience. According to Holling (1996), engineering resilience refers to stability, efficiency, constancy, predictability, return time to a previous state and, above all, to the idea of a single, stable equilibrium, using "resistance to disturbance and speed of return to equilibrium (…) to measure the property". On the opposite, ecological resilience emphasizes "conditions far from any equilibrium steady state", recognizes the existence of multiple equilibrium states and can be measured according to "the magnitude of disturbance that can be absorbed before a system changes its structure". Thus, ecological

resilience focuses on the twofold possibility for a system to absorb changes, maintaining its main features, below a given threshold of disturbance, or change its state, moving towards a different one, not necessarily better than the previous one, above such a threshold.
The engineering perspective has been largely widespread in the studies on risks, as opportunity for improving cities' capacities to deal with emergency and recover from disasters (e.g., IFRC, 2011; Vale and Campanella, 2005; Gunderson, 2010): according to this perspective, resilience has been interpreted as the capacity of a system to return to a previous equilibrium steady-state, to "bounce back" after disturbances.
The "ecological" approach to resilience has been significantly strengthened when the focus of studies and researches on resilience shifted from natural to socio-ecological systems and intertwined with those related to the complex adaptive systems, capable of learning from experience, processing the information, adapting and even transforming themselves in face to changes. By this perspective, resilience was less and less conceived as a bounce-back to a previous state and progressively adapted to the behavior of complex systems, that is non-linear, self-organizing, characterized by uncertainty and discontinuities (Berkes et al., 1998; Holling, 2001; Walker et al., 2004; Bankoff et al., 2004).
Recent research works have further extended the concept of resilience, defining the latter as a "dynamic interplay of persistence, adaptability and transformability across multiple scales" (Folke et al. 2010). Moreover, some scholars have pointed out the importance of "continual learning" (Cutter et al., 2008), providing an idea of resilience as 'bouncing forward', which includes the idea of 'improvement' of systems' essential structures and functions (IPCC, 2012).
Hence, current approaches to resilience seem more appropriate to grasp the complexity of urban systems' evolution (Davoudi, 2012; Chelleri et al., 2012) and suitable for framing urban policies in the face of a large set of heterogeneous phenomena, from the climate-related impacts to the scarcity of resources. In some cases, indeed, the concept of persistence, addressed to improve the capacity of a system to withstand sudden impacts and to rapidly and effectively recover previous conditions, can be significant. In other cases, being current conditions unsustainable or inadequate, novelty and innovation become crucial to drive the system's transition towards new conditions.
The milestones of the evolution path of the resilience concept are shown in fig. 6; it has to be noticed that the Resilient City definitions mainly refer to the more recent interpretation of Resilience, since it is generally interpreted as a city capable to absorb, adapt and/or change in the face of external pressures.

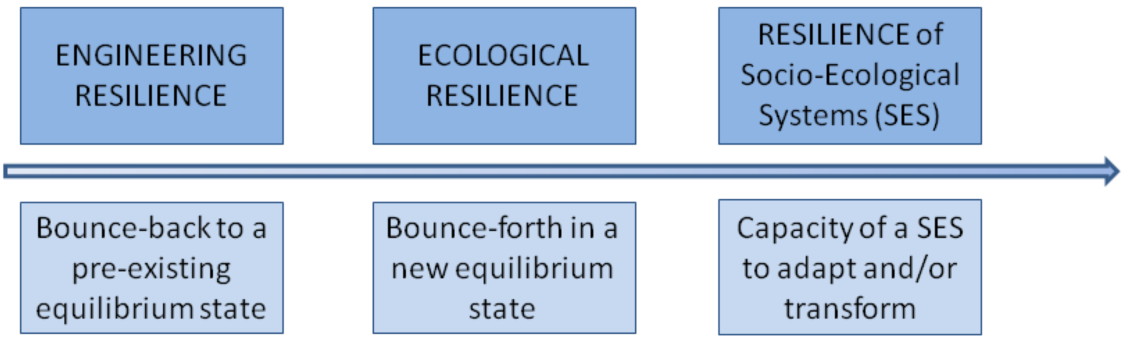


Fig. 6.Evolution of the Resilience concept

However, although the Resilient City concept is nowadays largely widespread among planners and decision makers, some scholars highlight the numerous criticalities that may arise when the resilience concept is applied to urban systems. For example, human intervention is not taken into account in the "adaptive cycle" of ecological systems, while it is crucial in case of urban systems; moreover, the need for clarifying the goals - "resilience to what ends?" – as well as the field of action - "resilience of what to what?" – and the beneficiaries - "resilience for whom?" – of policies addressed to enhance urban resilience have been largely emphasized (Davoudi, 2012).

These criticalities point out the need for improving urban resilience taking into account both "hard" and "soft" components of urban systems. The former refer to structural, technical, mechanical, and cyber systems' qualities, capabilities, and functions of infrastructures. The latter are "related to family, community, and society, focusing on human needs, behaviors, psychology, relationships, and endeavors" (Kahan et al., 2009). The difference between "hard" and "soft" components is also highlighted by some of the major networks devoted to the resilience issues (e.g., ICLEI, 2014; ACCCRN, 2012) and it is largely mirrored in the field of adaptation strategies and measures that are generally distinguished between "hard", when they "involve capital-intensive, large, complex, inflexible technology and infrastructure", and "soft", when they "prioritize natural capital, community control, simplicity and appropriateness" (Hallegatte, 2009; Sovacool, 2011).

Summing up, even though the term Smart City is rooted in the evolution and spread of ICTs and in their outcomes in terms of globalization of economy and markets, along its evolution path it has been increasingly used to indicate a city in which ICTs are addressed to improve the overall urban performances and, above all, the quality of life of citizens. The concept of resilience – which underlies the Resilient city concept – extending the concept of resilience from natural to socio-ecological and urban systems and embracing change and complexity, is more and more interpreted as a key concept for improving cities' performances in the face of the different factors currently threatening their future development, by managing a large set of interconnected properties and adaptive capacities (Norris et al., 2008; Galderisi and Ferrara, 2012).

Thus, both the concepts are currently interpreted as key concepts for improving urban performances, even though the Smart City concept puts large emphasis on the role of ICTs, while the Resilient City concept focuses on the inherent capabilities of cities to deal with the heterogeneous factors (from hazards to climate change, from environmental degradation to poverty) threatening cities' development. Moreover, both of them aim at providing strategies and measures acting on "hard" (infrastructures, technological systems, etc.) and "soft" components (capacities and behaviors of communities and institutions) of urban systems.

1.4 GOALS

Based on the analysis of the definitions and of the evolution paths of the Smart and Resilient City concepts some commonalities between the two concepts can be outlined, even though, as clearly highlighted in the previous paragraph, each concept has its own peculiarities. To further investigate the relationships between the two concepts, the main goals of each concept have been deepened.

According to the vast scientific literature on these issues, both the Smart City and Resilient City are mainly addressed to improve sustainability and increase the quality of life, although each concept seem to pursue these objectives following different paths.

As regards sustainability, in the Smart City this goal is primarily pursued through a wide use of ICTs that, allowing a more efficient and effective management of networks (energy, transport, etc.), may led to a significant reduction in energy consumptions. In a broader sense, "a smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects" (ITU, 2014).

Nevertheless, it is worth noting that the large use of ICTs may also negatively affect sustainability, at least in respect to:

- environmental aspects, in that the production of ICTs involves an intensive use of raw materials that are assembled in not recyclable devices (Wagener, 2008) and, above all, the use of ICTs induces high-energy consumption (Viitanen and Kingston, 2014). As remarked by Wagener (2007), indeed, "large cities with a high concentration of knowledge workers, office buildings, and ICT are likely to find that ICT energy use is significantly higher than national averages" (Wagener, 2007). Nevertheless, "green IT is a new emerging field of study that brings together both environmental sustainability and information technology (IT) and explores the ways in which they connect with each other" (Lombardi, 2011);

- socio-economic aspects, in that the use of "ICTs would increase the risk to human health, including stress and conflict due to inequality" (Viitanen and Kingston, 2014) among individuals and/or institutions that have access to ICT and that, above all, are able to use them properly.

Thus, according to current literature, social and environmental sustainability represent a "major strategic component of smart cities" (Caragliu et al., 2009), even though relevant aspects, such as the issues related to the potential of green ICTs or to the social inclusion, should be further investigated.

According to Folke (2002), resilience and sustainability are tightly connected concepts, due to the need for creating and maintaining prosperous social, economic and ecological systems also in the face of uncertain events. Some scholars emphasize that resilience represents a "necessary approach to meet the challenge of sustainable development" (Chelleri et al., 2012) or a way of thinking for planning sustainable cities, capable to meet "the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Report, 1987).

Nevertheless, similarly to what has been highlighted for the smart city, some scholars point out some inconsistencies between resilience and sustainability (TURAS, 2012; Redman, 2014): in detail, while resilience puts large emphasis on uncertainty and discontinuities and is largely interpreted as the result of the dynamic interplay of persistence, adaptability and transformability (Davoudi, 2012), sustainability is often interpreted in a "fail-safe" approach as a concept aimed at "achieving stability, practicing effective management and the control of change and growth" (Ahern, 2011)

The increase of the quality of life is the other main goal of both Smart and Resilient City. In the Smart City, the widespread use of ICTs allows, for example, "to improve mobility on many levels, increasing spatial and aspatial accessibilities to jobs, leisure, social opportunities and so on, thereby enabling the citizenry to increase their levels of life satisfaction" (Batty et al., 2012). Moreover, ICTs allow the reduction of energy consumptions and CO_2 emissions by allowing citizens to get a better air quality and a better environment.

The empowerment of citizens thanks to the use of ICT (Navarrete, 2012) represents a largely emphasized feature of the Smart City. It refers to a process of "social engagement" that creates a widespread sense of social cohesion, a significant awareness of the issues relevant to the community and allows people to propose and activate common objectives and actions (Zani, 2012). Thus, citizens' empowerment is a way to support decision-making processes based on a broad-base views of citizens and, therefore, to ensure development processes more participatory, collaborative and, in one, capable to effectively respond to the need of local communities.

Nevertheless, according to some scholars, "the paradox is that the same networked technologies that offer opportunities for empowerment can be used against civil rights for surveillance and censorship, or at worst, direct oppression" (Viitanen and Kingston, 2014).

Moreover, even though numerous scholars underline that the Smart City is addressed to increase "livability" (Toppeta, 2010; Chourabi et al., 2012; Smart City Council, 2014a), most of available definitions put "emphasis on business-led urban development" (Caragliu et al., 2009).

For example, the main aim of the study on European Smart Cities carried out by Giffinger et al. (2007) is to analyze the medium-sized European cities in order to find out their strengths and improve their competitiveness. The Smart City concept is, indeed, "principally open to any societal goals linked to it, but due to its focus on innovation systems, priority is given implicitly to competitiveness and economic growth" (Wolfram, 2012).

Also the Resilient City concept is addressed to increase the quality of life. A resilient city is, indeed, capable to absorb, adapt and/or change in the face of the main environmental challenges threatening its future, in order to preserve natural and man-made resources and, above all, to guarantee citizens' safety. It is worth reminding that, according to the five-stage model of human needs outlined by Maslow in 1943, safety is one of the basic needs that people have to fulfill, immediately after the biological and physiological ones. Therefore, to ensure the safety of people is a key objective for guaranteeing high levels of quality of life.

1.4 REMARKS

As it clearly arises from the above, the two investigated concepts, Smart City and Resilient City, show numerous commonalities, despite some differences. As regards the former, it has to be noticed that both of them result from a long and multidisciplinary evolution path capable to take into account the multiple and interrelated aspects of a complex urban systems, are addressed to pursue goals related to sustainability and quality of life and can be implemented through "hard" and "soft" measures.

Among the main differences, it is worth noting that while the spread of the Smart City concept has been strongly supported by large industries, the Resilient City concept has been mainly promoted by international organizations as well as by associations of cities and local governments.

Moreover, whereas the common ground among the definitions of Smart City can be found in the use of ICTs as a tool for empowering cities and citizens in the face of heterogeneous challenges, but above all as a key tool to fuel economic growth and competitiveness, the common ground of the definitions of Resilient City can be traced in the enforcement of the fundamental capacities of an urban system to deal with external pressures (from climate change to environmental degradation).

Nevertheless, according to the more recent interpretations of the Smart City concepts, ICTs should be better addressed to solve long-term environmental challenges and to improve cities' resilience rather than primarily focus on consumer electronics. According to Heeks et al. (2013), indeed, "ICTs can help strengthen the physical preparedness of communities by helping those communities to optimize the location of physical defenses" and "can also strengthen institutions needed for the system to withstand the occurrence of climatic events".

Hence, the Smart City concept seems more and more to underlie a process, a multi-objective strategy of integrated urban and ICT development, capable to tackle problems of economic competitiveness but also of social equity and environmental performance (Wolfram, 2012). Such a process should allow cities to "become more livable and resilient and, hence, able to respond quicker to new challenges" (Kunzmann, 2014).

Therefore, a better integration between the two often separate concepts and following strategies seem to be widely desirable and already pursued by some. Nevertheless, such integration has to be based on a robust scientific approach capable to provide methodological and operational tools for promoting cross-sectoral and multi-objective strategies capable to improve urban smartness and resilience, by providing citizens with a better urban environment capable to favor cohesion, sense of community and, meanwhile, safety and prosperity. Moreover, it is worth emphasizing that a multi-objective strategy addressed to build up a smarter and a more resilient city should be carefully tailored on the peculiarities of local contexts, in that each city has to define its own objectives and priorities, through a shared and participatory process (BSI, 2014).

2. SMART AND RESILIENT CITIES: TOWARDS AN OPERATIONAL APPROACH

According to the preliminary findings presented in the previous paragraph, it seems possible to state that, on the one hand, the Smart City concept is widely interpreted as a process capable to tackle urban problems related to economic competitiveness but more and more and more focused on issues related to social equity and environmental performances (Wolfram, 2012). On the other hand, the Resilient City is largely interpreted as a process addressed to empower cities and citizens to cope with external - environmental, social, economic - pressures. Hence, due to the relevant synergies between the two concepts, some authors emphasize the increasing area of overlap among them, comprising resilience among the Smart Cities' objectives and highlighting that smart initiatives should allow cities to "become more livable and resilient and, hence, able to respond quicker to new challenges" (Kunzmann, 2014). Moreover, some international organizations and networks as well as numerous cities are promoting integrated strategies for building up smarter and more resilient cities, as a key step for effectively counterbalance the challenge of climate change as well as for pursuing a better integration between mitigation and adaptation strategies (Klein et al., 2005). For example, the American Planning Association (APA) has "created a Smart Cities and Sustainability Task Force, whose mission is to address advances in technology and innovation to cultivate cities which are smarter, more resilient and sustainable" (McMahon, 2014); the Asian Cities Climate Change Resilience Network (ACCCRN), funded by the Rockefeller Foundation, is striving for "developing smarter, resilient cities in India" (ACCCRN, 2015).

Nevertheless, as mentioned above, operational tools capable to support these strategies are still at an early stage. To fill this gap, grounding on a systemic approach and based on an in-depth review of existing literature, the main characteristics of a smart and resilient urban system will be identified. Then, they will be selected and arranged into a conceptual model capable to represent their roles and linkages along the path addressed to improve the response capacities of complex urban systems in the face of climate change. Finally, in order to better understand whether and how such a model may contribute to frame current mitigation and adaptation strategies, the case study of Rotterdam – already striving for integrating smart and resilient initiatives addressed to mitigate and adapt to climate change – will be analyzed.

2.1 THE CHARACTERISTICS OF A SMART AND RESILIENT CITY

Based on the review of scientific literature, the main characteristics of the Smart City and the Resilient City have been collected (Table 3). It is worth firstly underlining that most literature related to the resilience of socio-ecological systems emphasizes the concept of self-organization, interpreted as a key feature of a resilient system (Walker et al., 2004; Chuvarajan et al., 2006; Folke et al., 2006). However, according to numerous scholars, self-organization has been here interpreted as an inherent characteristic of complex systems, such as the urban systems. It "can be defined", indeed, "as the spontaneous emergence of global structure out of local interactions. Spontaneous means that no internal or external agent is in control of the process (…). This makes the resulting organization intrinsically robust and resistant to damage and perturbations" (Heylighen, 2008). According to such interpretation, self-organization has not been included among the characteristics to which strategies and action for improving cities' response in the face of climate change have to be directly addressed: nevertheless, self-organizing mechanisms that will arise as a consequence of the internal and external changes of the systems, should be adequately monitored and understood.

The table 3 shows the numerous characteristics common to the Smart City and the Resilient City concepts. Beside them, the table includes some characteristics that are the most frequently quoted in the analyzed literature, even though in respect to one of the two concepts.

Then, in the Table 4, for each characteristic the most shared definitions in current literature have been listed, with reference to both Smart City and Resilient City. In some cases, indeed, although the characteristics are common, more or less significant differences in the way they are interpreted in respect to each concept can be found.

RESILIENT CITY CHARACTERISTICS		SMART CITY CHARACTERISTICS
· Efficiency	· Knowledge	Efficiency
· Flexibility	· Collaboration	Flexibility
· Adaptability	· Persistence	Adaptability
· Networking capacity	· Resistance	Networking capacity (interoperability, connectivity, communication capacity)
· Connectivity	· Modularity	Learning capacity
· Learning capacity	· Redundancy	Diversity (social and ethnic plurality)
· Diversity	· Memory	Innovation capacity
· Innovation capacity	· Robustness	Creativity
· Creativity	· Resourcefulness	Participation (civic engagement, cohesion)
· Participation (community involvement)	· Transformability	Awareness
· Awareness		Collaboration
		Equity (fairness, social inclusion)
		Monitoring capacity
		Reliability
		Anticipation

Table 3. Characteristics of Resilient City and Smart City

CHARACTERISTIC	CONCEPT	DEFINITION
Efficiency	Resilient City	“Efficiency represents a fundamental property for service system and entails that performance are realized with modest resource consumption” (Fiksel, 2003)
Efficiency	Smart City	Efficiency is related to the capacity of systems and infrastructures to optimize their performances (Aoun, 2013; Kramers et al., 2014)
Flexibility	Resilient City	It is recognized as a key aspect of adaptive capacity when unexpected events occur (Godshalk, 2003) and can be defined as the capacity of a system to cope with an impact without being permanently altered (Tasan-Kok, 2013)
Flexibility	Smart City	It is the ability to change, specifically referred to labor market and human capital (Giffinger et al., 2007)
Adaptability	Resilient City	It represents the “capacity to maintain a system in its current stability domain” (Berkes et al., 2002)
Adaptability	Smart City	It can be considered as the capacity to adapt to unforeseen situations (Ratti and Townsend, 2011)
Networking capacity	Resilient City	It can be defined as the ability to create networks consisting of non-identical elements, or actors, called “nodes” that are connected by diverse interactions or links (Chuvarayan et al., 2006)
Networking capacity	Smart City	Capacity to connect computers and devices through communications channels that facilitate communications among users, allowing them to share resources and services (BSI, 2014)
Connectivity	Resilient City	It is related to “the density of the links within the network, i.e., the number of links divided by the maximum possible number of links” and to the “reachability, or the extent to which all the nodes in the

		network are accessible to each other" (Janssen et al., 2006)
Learning Capacity	Resilient City	Dynamic systems require to constantly revise existing knowledge to enable the management of the system and the adaptation to change (Stockholm Resilient Centre, 2014)
Learning Capacity	Smart City	It can be defined as the human ability to gain knowledge or skill through ICT (Coe et al., 2001) or as the collection of data and their elaboration (Wolfram, 2012)
Diversity	Resilient City	Diversity of species performing critical functions, diversity of knowledge, institutions and human opportunity and diversity of economic supports all have the potential to contribute to sustainability and adaptive opportunity (Berkes et al., 2002)
Diversity	Smart City	It can be referred to the social and ethnic plurality (Giffinger et al., 2007) or to the diversity of specific elements, e.g. transportation modes (Caragliu et al., 2009).
Innovation	Resilient City	"Innovation is seen as novel ways of doing things, or how new things can be made useful, and refers to incremental or radical changes in ideas, practices, and products; including novel ways of organizing society, changing its rules and institutions" (Ernstson et al., 2010)
Innovation	Smart City	Changes made to something established, or a new introduction as new methods, ideas, or products, to achieve desirable outcomes that result in small but significant improvement (BSI, 2014)
Creativity	Resilient City	Creativity represents the achievement of higher level of functioning by adapting to new circumstances and learning from the disaster experience (Maguire and Hagan, 2007)
Creativity	Smart City	It is related to the creative capital that co-determines, fosters and reinforces trends of skilled migration (Florida, 2003; Caragliu and Nijkamp, 2008)
Participation capacity	Resilient City	It is the capacity to "build trust and relationships needed to improve legitimacy of knowledge and authority during decision making processes", as well as "create a shared understanding and uncover perspectives that may not be acquired through more traditional scientific processes" (Rockefeller Foundation, 2014)
Participation capacity	Smart City	It can be defined as the capacity to involve civil society organizations, stakeholders, communities and citizens in policy-making and public debate (BSI, 2014)
Awareness	Resilient City	"It's the ability to constantly assess, take in new information, reassess and adjust your understanding of the most critical and relevant strengths and weaknesses and other factors on the fly" (Rockefeller Foundation, 2014)
Awareness	Smart City	N.A. However, it is related to the capacity of knowing and understand the urban potentialities (Giffinger et al., 2007)
Collaboration	Resilient City	It refers to the existence of multiple opportunities and incentives for a broad participation of stakeholders, as in public-private partnerships (Godschalk, 2003).

Collaboration	Smart City	It is closely related to coordination and is defined as a step of the city technology harmonization, characterized by synergies and interactions between elements, resource and actors within the urban system (BSI, 2014)
Redundancy	Resilient City	Spare, superfluous or substitutable "elements, systems, or other units (..) capable of satisfying functional requirements in the event of disruption, degradation, or loss of functionality" (Bruneau et al., 2003; Walker and Salt, 2006; Schultz et al., 2012; Tyler and Moench, 2012).
Resistance	Resilient City	The degree to which systems are displaced (or disturbed) by a given physical force or pressure (Carpenter et al., 2001)
Persistence	Resilient City	System's ability to withstand an impact, preserving its own characteristics and structure, except for a temporary departure from the ordinary functioning conditions (Folke et al., 2010)
Modularity	Resilient City	"It is the degree to which a system's components may be separated and recombined" (Elmqvist, 2013)
Robustness	Resilient City	The "ability of elements, systems, and other units of analysis to withstand a given level of stress or demand without suffering degradation or loss of function" (Bruneau et al., 2003).
Resourcefulness	Resilient City	"The capacity to (…) mobilize resources when conditions exist that threaten to disrupt some element, system, or other unit of analysis" including "the ability to apply material (i.e., money, physical, technological, and informational) and human resources to meet established priorities and achieve goals" (Bruneau et al., 2003)
Memory	Resilient City	"The ability of a system to preserve knowledge and information" (Folke et al., 2005)
Transformability	Resilient City	"Capacity of people to create a fundamentally new social-ecological system when ecological, political, social or economic conditions make the existing system untenable" (Walker et al., 2004)
Knowledge	Resilient City	The capacity to elaborate knowledge and learn from management mistakes, protecting a system from the failure due to subsequent management actions based on incomplete knowledge and understanding (Berkes, 2004)
Monitoring	Smart City	"The capacity to monitor all critical infrastructures is crucial for a smart city in order to better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens" (Hall, 2000)
Reliability	Smart City	Degree to which a measure repeatedly and consistently produces the same result (BSI, 2014)
Anticipation	Smart City	It can be defined as the capacity to conceive future predictable scenarios. Indeed, a smart city can provide "tools to exploit various sources of information about human behavior to aid in the allocation of resources—land, water, transportation, and so on—as the city evolves" (Naphade et al., 2011)

Table 4. Characteristics of Smart City and Resilient City

So far the characteristics of a smart and a resilient city have been listed and briefly explained. Nevertheless, to better understand how these characteristics act and above all interact each other for improving the response capacities of complex urban systems in the face of climate change, a further step is required. Climate change represents, indeed, a challenging threat that requires long term as well as short-medium term strategies. Indeed, on the one hand, long-term strategies capable to reduce GHG emissions and energy consumptions, to improve energy efficiency and to progressively switch towards low-carbon energy sources; on the other hand, short-medium term strategies aimed at reducing the vulnerability of urban systems to its heterogeneous impacts, ranging from sudden (as flash floods, heat waves, etc.) to slow phenomena (as droughts).

Therefore, in order to highlight roles and linkages of the different characteristics in respect to the different time spans (short-medium-long term) that characterize the response of a complex urban system in the face of climate change; they have been arranged into a conceptual model (Fig. 7).

It is worth firstly reminding that the most recent approaches to the resilience concept provide an interpretation of the latter as the "dynamic interplay of persistence, adaptability and transformability across multiple scales" (Folke et al., 2010). Grounding on this, a resilient system extends its focus beyond resistance to shocks to include adaptive responses as well as long-term transformation in the face of future or unforeseen threats (Galderisi, 2014). Moreover, some scholars point out the key role of the learning capacity for improving both urban resilience (Davoudi et al., 2013) and smartness (Wolfram, 2012).

The capacity of "continual learning" (Cutter et al., 2008) is crucial, indeed, for enhancing the chances of urban systems "of resisting disturbances (being persistent and robust), absorbing disturbances (…) (being flexible and adaptable) and moving towards a more desirable trajectory (being innovative and transformative)" (Davoudi et al., 2013). Hence, it may allow urban systems to improve their robustness in the face of climate-related impacts as well as to "bouncing forward", including the idea of anticipation and "improvement" of their essential structures and functions that are crucial to long-term strategies (IPCC, 2012).

According to these interpretations, persistence, adaptability, transformability and learning capacity have been classified as key properties of a smart and resilient city or, better, as the main goals to which strategies and measures have to be addressed for improving cities' response in the face of climate change. All the other characteristics, according to their meanings, have been related to one or more of the identified key goals: they represent indeed the characteristics that should be improved in order to achieve each of the mentioned goals.

In detail, learning capacity can be improved through strategies and actions addressed to enhance: monitoring capacity, which allows to constantly detect the conditions of an urban system; knowledge that allows to elaborate information about events and processes; memory, which allows to learn from past events in order to figure out possible future scenarios; collaboration, which favors interactions and synergies between different stakeholders; networking capacity that allows to connect people and devices for exchanging data and information; participation, which allows to involve people in the decision-making processes. Moreover, learning capacity is intended crucial for developing people and institutions' awareness about climate-related issues, to improve the capacity to anticipate likely future events, which can threaten urban systems, and, mainly grounding on monitoring and knowledge, to guarantee an effective management of the urban system along the time. Finally, as emphasized above, learning capacity provides inputs for enhancing persistence, adaptability and transformation of the system in the face of climate change: these properties, which come to the fore in different temporal stages, provide in turn information that, being continuously processed, can be used as an input to further increase the learning capacity (feedback loop).

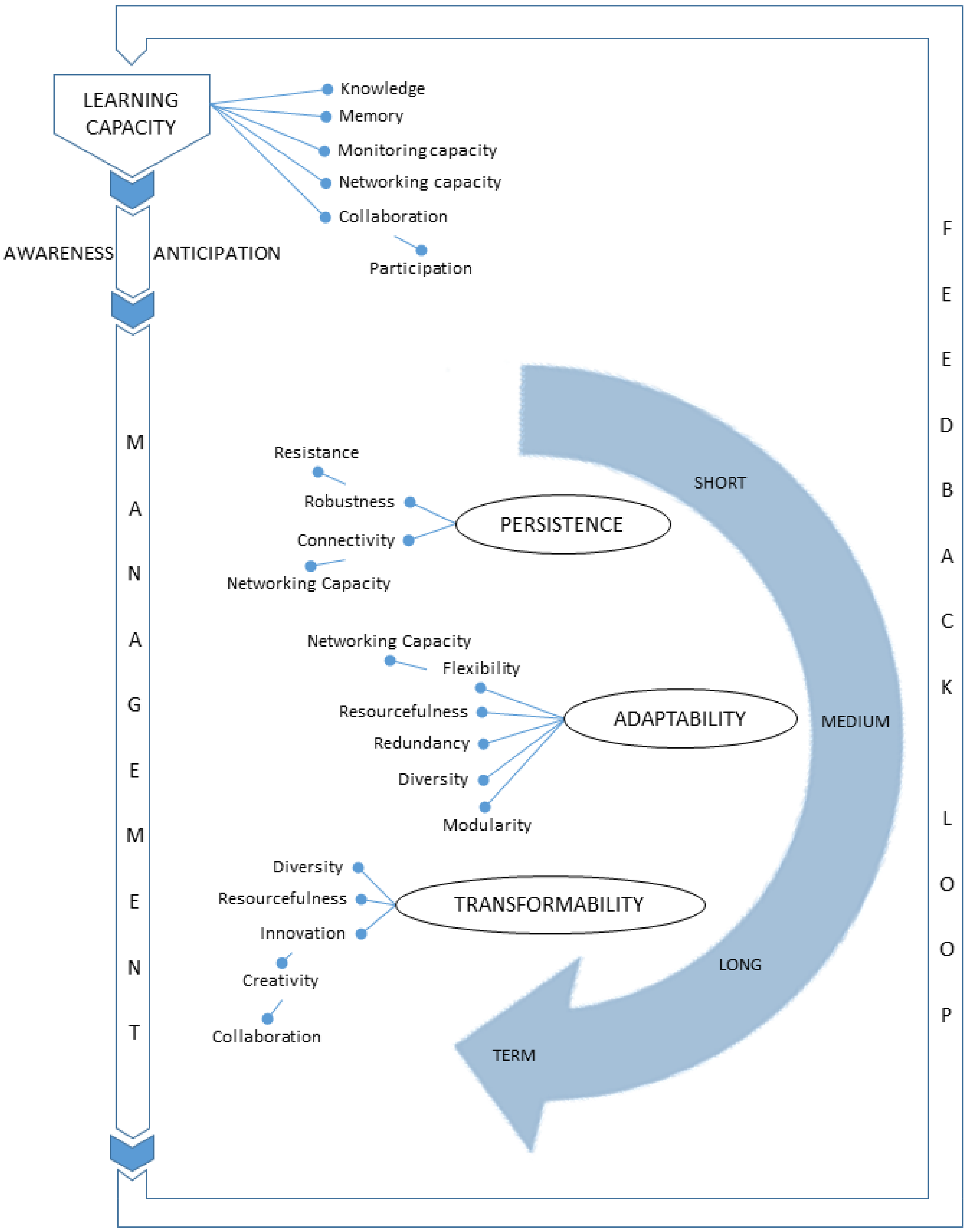


Fig. 7. The conceptual model shows roles of and linkages among the capacities that may contribute to improve the response capacities of complex urban systems in the face of climate change.

Persistence, generally referred to the ability of an urban system to maintain the characteristics and structures in the face of a threatening factor, can be improved through strategies and actions addressed to enhance: robustness, which is the ability of elements and systems to withstand a given impact without suffering degradation or loss of function (Bruneau et al., 2003); resistance that allows the urban system to not be displaced (or disturbed) by a given pressure (Carpenter et al., 2001); networking capacity, which refers to the ability to create networks of non-identical elements or actors, connected by diverse interactions or links (Chuvarayan et al., 2006); connectivity, related to the density of links within a network and to the extent to which all the nodes of the network are accessible to each other (Janssen et al., 2006).

Indeed, higher the ability to create connections, higher the number of connections and, therefore, higher the possibility that the urban system persists in the face of a pressure, maintaining its structure. In an integrated smart and resilient system, the networking capacity regards also the capacity to connect computers and devices, since the information exchange increases the urban system persistence, supporting for example the real time mobilization of resources and services where they are needed.

Adaptability, generally related to the capacity of an urban system to adapt itself to unforeseen situations (Ratti and Townsend, 2011), can be improved through strategies and actions addressed to enhance: flexibility that, in opposition to hierarchical organizations, allows a system to be changed or adjusted to meet particular or changing needs; diversity that, recognized as crucial in case of impacts of adverse events, allows a system to better cope with uncertainty and surprise; a diverse economy ensures, for example that there is overall economic viability if one economic activity fails (Berkes et al. 2002); resourcefulness that refers to the availability of ecological, economic, social and cultural capital, allows the system to better cope with external pressures; modularity, which allows to recombine the elements of a system, supporting the transition towards different configurations; redundancy, which allows the system to count on superfluous/substitutable elements for adapting adaptable in the face of pressures.

Finally, transformability that represents the capacity to create a fundamentally new system when ecological, political, social or economic conditions make the existing one untenable (Walker et al., 2004), can be improved through strategies and actions addressed to enhance: innovation in all elements and sectors of urban systems, from the physical to immaterial aspects, comprising the introduction of new methods, ideas, products or processes to achieve desirable outcomes (BSI, 2014); creativity, which generally results from research and experimentation that provide spurs for innovating cities in face of complex and unpredictable events; collaboration that allows to exchange new information and inputs and fosters creativity; resourcefulness, which refers to the ability to mobilize and use the available resources supporting the transition of the system towards new configurations; diversity and modularity that allow elements to be separated and connected in new configurations.

2.2 CHARACTERISTICS IN THE COMPLEX URBAN SYSTEM: THE ROTTERDAM CASE STUDY

In the previous paragraphs, the main characteristics of a smart and resilient city have been selected, analyzed and arranged into a model aimed at driving multi-objective strategies in the face of climate-related issues. Then, in order to better understand whether and how such a model may contribute to frame and guide current mitigation and adaptation strategies, the case study of Rotterdam – striving for integrating smart and resilient initiatives addressed to mitigate and adapt to climate change – has been analyzed.

In detail, the model might allow to understand whether and how strategies and measures undertaken at the city level may contribute to enhance the different characteristics of a smart and resilient urban system and, namely, of its main subsystems. According to the interpretation of the city as a complex and dynamic system (Batty, 2008), indeed, the latter can be articulated in different urban subsystems. Such subsystems can be sketched as follows: physical, comprising buildings and network infrastructures; functional, including activities and communications flows; socio-economic and institutional, comprising all urban stakeholders as well as economic activities; and natural environment, comprising all natural resources as soil, subsoil, air, water, vegetation and fauna (Papa et al. 2009).

In the last seven years Rotterdam has undertaken a sustainable development policy addressed to integrate smart and resilient initiatives in the face of climate-related issues, promoting meanwhile mitigation and adaptation strategies. In 2014 the New Economy has assigned the Smart Cities Awards to Rotterdam, as "the city of the future" in the field of sustainable development. This award was related to the path followed by the city both in tackling climate issues and promoting its image as the most sustainable port in the world.

The Rotterdam case study has been analyzed focusing first of all on the crucial factors that have determined current policies and then on the national and local strategies and related measures.

These measures have been grouped according both to the European classification in Soft Approaches, Grey Infrastructure Approaches and Green Infrastructure Approaches (EEA, 2012) and to their similarities (e.g. actions on rainwater harvesting or measures for dissemination of information and best-practices). As a result, we defined three groups of measures: soft measures which refer to Soft Approaches; grey measures which refer to Grey Infrastructure Approaches and, finally, green measures which refer to Green Infrastructure Approaches. Then, each group has been related to the selected characteristics of a smart and resilient system and to its subsystems (fig. 8, 9, 10). Finally, among these measures, four measures have been in-depth analyzed: the Water Square Benthemplein, the System of Green Roofs, Floating Pavilions, Cleaner Air by Means of Dynamic Traffic Management. They represent, indeed, clear examples of integrated solutions, capable to address different objectives, by combining mitigation and adaptation issues, by using ICTs, and by largely promoting citizens' participation.

The Rotterdam sustainable development policy – capable to combine smart and resilient initiatives as well as mitigation and adaptation strategies – seem to be developed due to the convergence among three main factors:

- the morphological and climate features of Rotterdam;
- the size of the city and the relevance of its Port;
- the key role of the Port Authority and the establishment of a public-private partnership.

As regards the first factor, it is worth noting that Rotterdam is a river town and the 90% of the urbanized area is below the sea level. This particular morphology has historically made Rotterdam a flood prone area. However, flooding phenomena have recently intensified and they are expected to further increase in the next future. The annual precipitation is about 800 mm (31.5 inches) per year. The monthly totals of precipitation are evenly distributed throughout the year, while the intensity of rainfall events largely increases in summer. Heat waves represent another significant consequence of climate change, with temperatures above 30° C, which are expected to be more and more frequent in the next future. Hence, heat waves and floods represent the major environmental challenges that the city of Rotterdam has to deal with.

As regards the second factor, the Rotterdam city center has area of 319.35 km² (206.44 km² of land and 112.91 km² of water), and has a total population of about 610.386 inhabitants (2011). Nevertheless, strategies and initiatives addressed to increase urban "smartness", by combining mitigation and adaptation, extend their focuses from the city center to the metropolitan area of the "Randstad", which has a population of about 1.003.088 inhabitants (2011). The close relation between the city center and the metropolitan area is mainly due to the presence of the port, an hub for raw materials and other goods between Europe and numerous destination all around the world, which has a strategic economic role on local, national and European level.

As regards the third factor, it has to be underlined that, due to the economic relevance of the port basin, the Rotterdam Port Authority was largely interested in promoting and implementing smart initiatives addressed to increase urban and regional capacity to cope with extreme events. Hence, the Port Authority, together with the Municipality of Rotterdam, the Environmental Protection Agency Rijnmond (DCMR) and the Deltalinqs (Group of Industrial and Logistic societies in the Port of Rotterdam), has established a Public Private Partnership: the Rotterdam Climate Initiative (RCI)[1], which aims at implementing strategies for mitigation and adaptation, to cope with extreme challenges resulting from climate change, in respect to the scenario forecasts to 2050.

The RCI promotes and shares measures related to mitigation and adaptation strategies related to five priority axes:

[1] http://www.rotterdamclimateinitiative.nl/

- Hydraulic safety of the Delta of Rotterdam;
- Accessibility of the Port for the transport of both freights and passengers;
- Adaptive Buildings;
- Urban water system;
- Climate city.

This five axes refer to strategies undertaken both on National and local level: the Delta Programme 2015 (National), the National Adaptation Strategy NAS (National), the Water Plan 2 Rotterdam (local), the Rotterdam Climate Change Adaptation Strategy CCAS (locale), the Sustainable Energy Action Plan SEAP (local). These strategies are mainly addressed to guarantee the safety of both the port area and city-region by reducing vulnerabilities and risks arising from the intense rains and heat waves. Moreover, the strategies are addressed to preserve water resources, interpreted as crucial for sustainable development of the Rotterdam Regional Area, and namely drinking water supply. Furthermore, they promote measures capable to integrate mitigation, by reducing CO_2 emissions in accordance with the guidelines of the SEAP (2009), and adaptation: for example, the Floating Pavilions, which are designed to adapt to the rising water levels, are also intended as low-carbon buildings, relying on renewable energy sources.

Based on the mitigation and adaptation strategies and measures reported by the RCI, the study has investigated the relationships among these strategies and measures, the selected characteristics of a smart and resilient urban system and the urban subsystems. Specifically, the linkages between mitigation and adaptation measures, as well as characteristics and subsystems, have been summarized in the following diagrams (figs. 8, 9, 10). Each diagram shows adaptation (yellow) and mitigation strategies (blue). Moreover, initiatives and measures have been grouped according to their objectives and features in soft measures, grey measures and green measures, according to the EEA classification (2012). Then, each measure or group of measures have been related both to the characteristics, which could be increased by the measure, and to the urban subsystems.

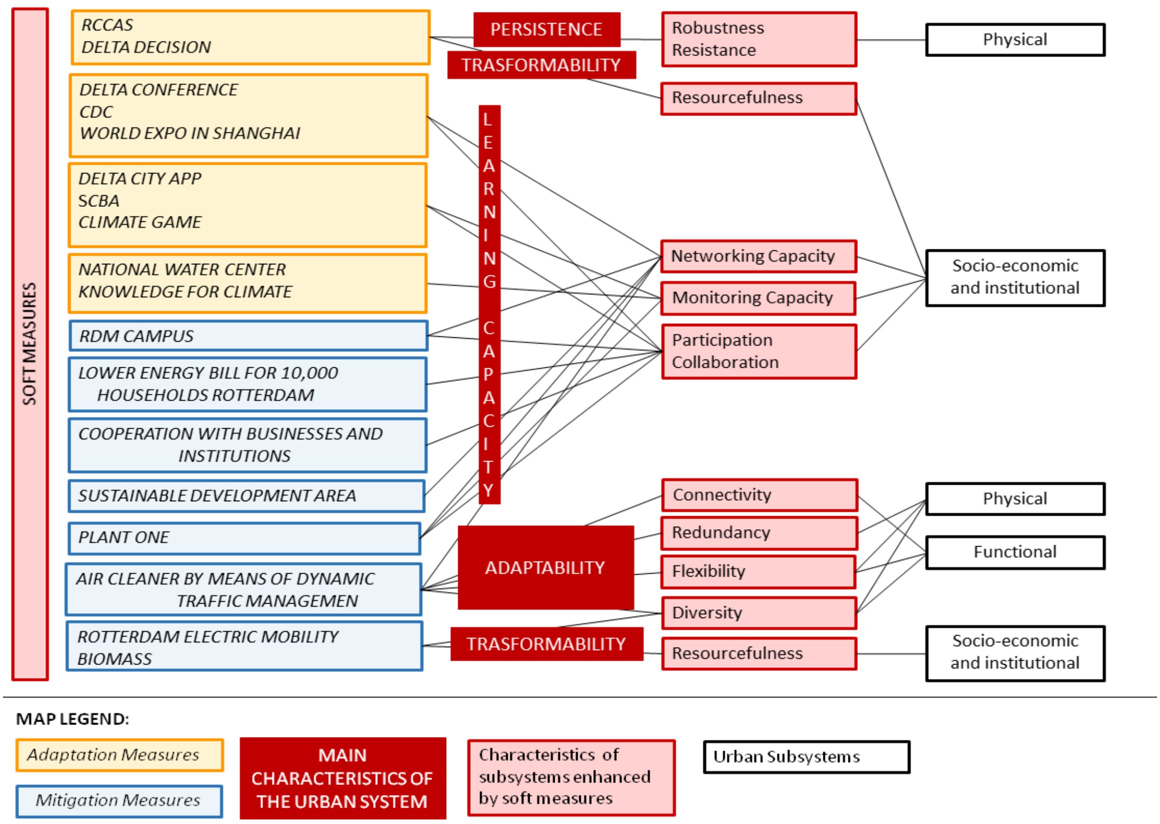


Fig. 8. Soft Measures - Linkages between mitigation and adaptation measures, as well as characteristics and subsystems.

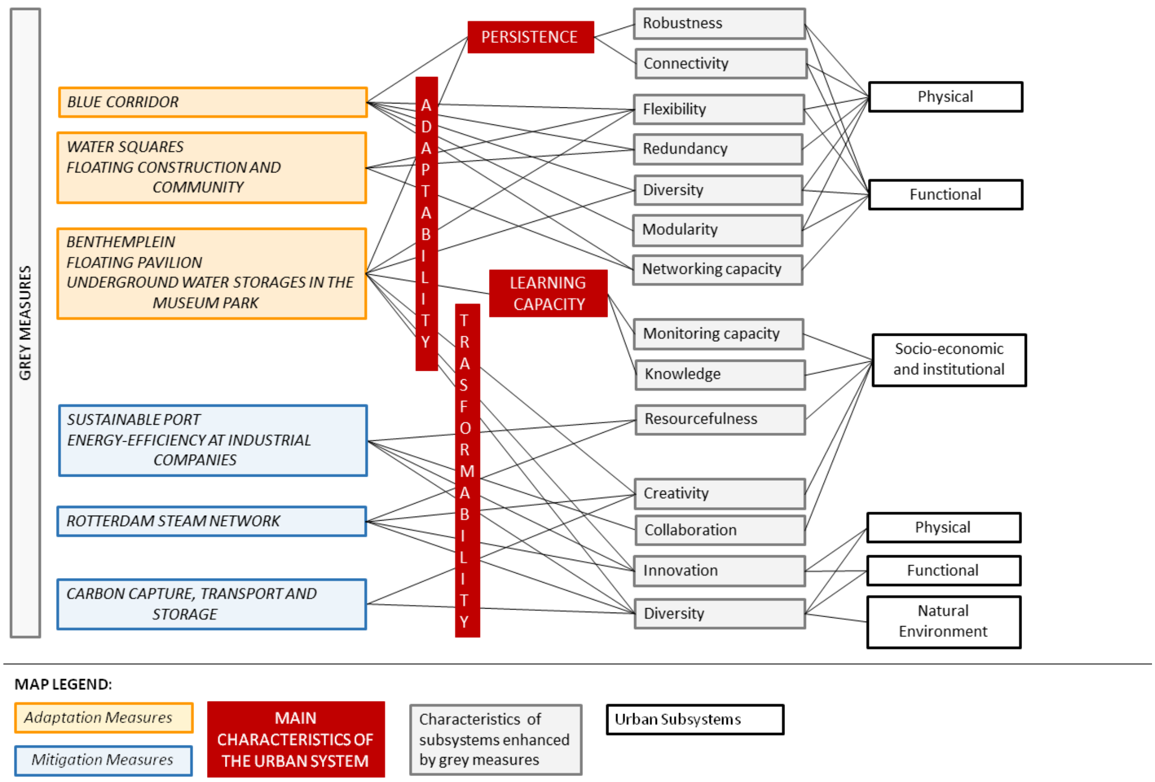


Fig. 9. Grey Measures - Linkages between mitigation and adaptation measures, as well as characteristics and subsystems.

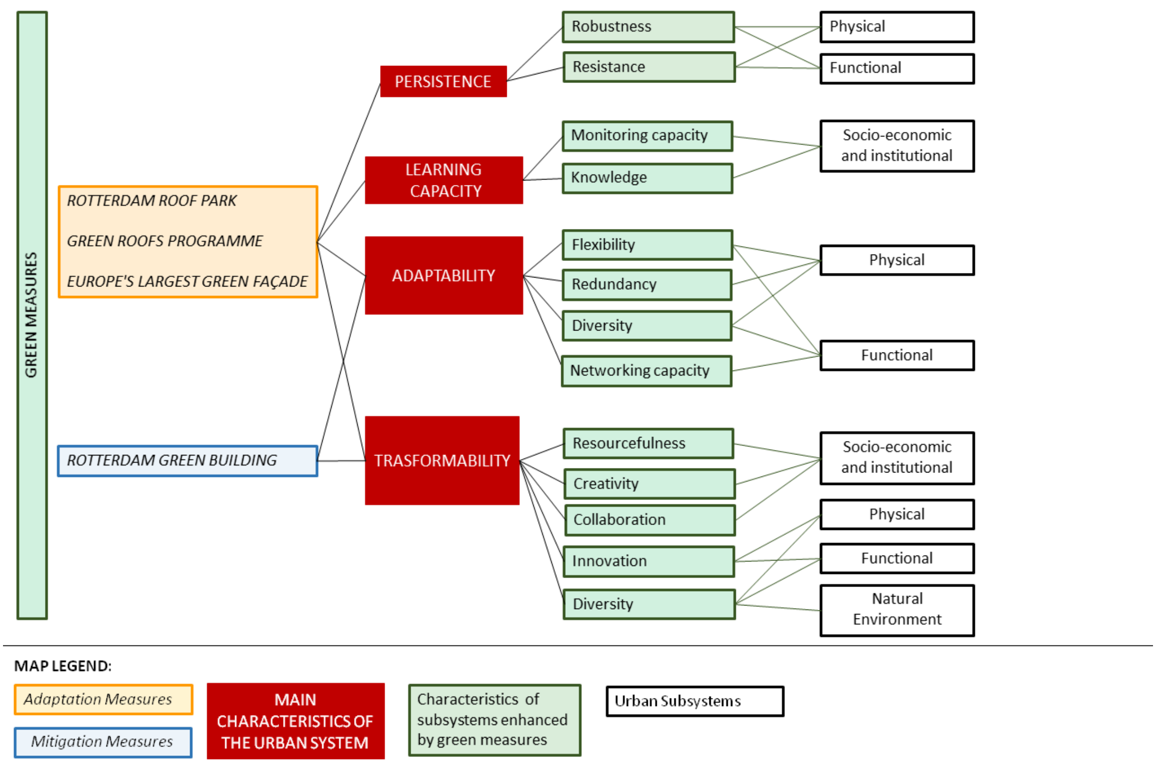


Fig. 10. Green Measures - Linkages between mitigation and adaptation measures, as well as characteristics and subsystems.

Focusing on adaptation strategies – aimed at building up a climate proof city and largely focused on water resource as opportunity to renew and change the city – 23 measures have been analyzed.

Most of them can be classified as soft measures (16): they are addressed to increase learning capacity, by enhancing networking capacity, monitoring capacity, collaboration and citizens' participation and mainly affect the socio-economic and institutional urban subsystem. In detail, these measure support the building up of networks and tools for sharing and disseminating information and best practices (e.g. the Delta Conference, the CDC and the World Expo in Shanghai, the Delta City App, the SCBA and the Climate Game) and promote research activities capable to support adaptation strategies (e.g. the National Water Center and Knowledge for Climate and the Plant One). Another group of soft measures, the Rotterdam Climate Change Adaptation Strategy (RCCAS) and the Delta Decision, enhance physical subsystem persistence by improving resistance and robustness. In detail, these measures provide guidelines for a new plan of the complex water system infrastructure, comprising storm surges barriers and dikes, canal and lakes, sewers and pumping stations in the Rotterdam area.

Among the grey measures, some projects related to rainwater harvesting (Benthemplein, Underground water storages in the museum park, Water squares), floating constructions (Floating Pavilion, Floating Construction and Community) and improvement of drinking water (Blue Corridor) have been analyzed. Some of the measures included in these projects aim at increasing learning capacity: for example, the Benthemplein and the Floating Pavilion – being pilot projects – are constantly monitored in order to improve current knowledge about their capacity to cope with climate impacts and their potential of being extended to other urban areas.

Others mainly related to physical and functional urban subsystems are addressed to increase persistence, by improving robustness and connectivity, and adaptability, by enhancing flexibility and networking capacity, redundancy, diversity and modularity. For example, the Blue Corridor, a new waterway corridor in southern Rotterdam, allows to increase both the diversity, by providing new water resources to the southern part of the city, and the flexibility of the water supply system, serving as water supply line in case of drought. Moreover, the project related to the Floating Pavilion supports transformability in a long-term perspective, since the innovative pavilions respond to the objectives of Rotterdam to reduce emissions of CO_2 by 50% thanks to innovative building materials and innovative systems used for guaranteeing internal comfort conditions. Also adaptability is increased thanks to the possibility of such pavilions to float depending on the rising of the sea level.

In respect to green measures, some projects aimed at improving green roofs and green facades in the urban area (Rotterdam Roof Park, Green Roofs Programme, Europe's Largest Green Façade) and one project addressed to build up a natural basin for collecting rainwater outside the urban center and meanwhile to provide a new recreational area have been analyzed. These projects comprise measures addressed to increase learning capacity, by improving monitoring capacity and knowledge. Moreover, in relation to the physical and functional subsystems, such measures improve adaptability, since they are aimed at both absorbing in-excess rainwater and extend the lifespan of the roofs, and reducing runoff speed and pressure on the sewage system during heavy rainfall by increasing, in such a way, flexibility, redundancy and diversity.

Looking at mitigation strategies, whose goal is the 50% reduction of CO_2 emissions by 2025, thirteen measures have been identified. Most of them can be classified as soft measures, introduced by urban development programs and initiatives, such as the Sustainable Development Area, Rotterdam Promotes Electric Mobility, Biomass, Lower Energy Bill for 10000 Households Rotterdam, Cooperation with Businesses and Institutions RDM CAMPUS, Air Cleaner By Means Of Dynamic Traffic Management. These measures aim at increasing learning capacity, by enhancing networking capacity, monitoring capacity, collaboration and participation. For example, the Lower Energy Bill for 10000 Households Rotterdam measure allows citizens to monitor their consumptions, increasing learning capacity and, meanwhile, people awareness about their energy behaviors.

Grey measures comprise projects and measures on natural, physical and functional urban subsystems aimed at increasing transformability by reinforcing resourcefulness, creativity, collaboration, innovation and diversity (e.g. Sustainable Port, Rotterdam Steam Network, Carbon Capture, Transport and Storage, Energy-Efficiency At Industrial Companies). For example, the Carbon Capture, Transport and Storage represents an innovative project addressed to reduce CO_2 emissions produced by industries through the capture of CO_2 emissions by means of an underground network. Such a network allows the re-use CO_2 in the greenhouses and in food industry or the permanent underground storage of CO_2 for enhancing oil and gas recovery. Therefore, it provides innovation, enhancing the transition of the urban system towards a low-carbon system.

Green measures have been mainly addressed to save energy and reduce water consumptions in public buildings. Among measures included in green measures, the Rotterdam Green Building Programme has to be mentioned. Indeed, such Programme aims at realizing more sustainable buildings and clusters by taking energy and water saving measures that allow the increase of the transformability, for example, through the use of innovative low energy systems in buildings.

Finally, it is worth noting that, despite the attempt to bring strategies and measures to one or another category (soft, grey, green, mitigation, adaptation), the most interesting on-going projects and initiatives comprise all the different types of measures (soft, grey, green) and are strategic both for adaptation and mitigation goals. Among them, we will briefly focus here on the Water Square Benthemplein, the Green Roofs Programme, the Floating Pavilion and the Cleaner Air By Means Of Dynamic Traffic Management.

In detail the Water Square Benthemplein, completed in the late 2013, is the first public water park in the world fed by collected rainwater (Fig. 11). It is a pilot project that, if successful, will be replicated in different urban areas of Rotterdam. The square is designed with two large basins, used both for collecting rainwater and as outdoor sport venue. Indeed, during heavy rain falls, the two basins collect the rainwater from the streets and the rooftops of nearby buildings, properly channeled, and filtered through a system to green both in roofing and in based area, up to about 1.7 million liters. The building up and the management of green roofs and flowerbeds is in charge of private owners which have to follow rules and instructions provided by local authorities. The water, once collected in the square, is then allowed to flow through the pipes to the river thanks to a mechanical and electronic systems.

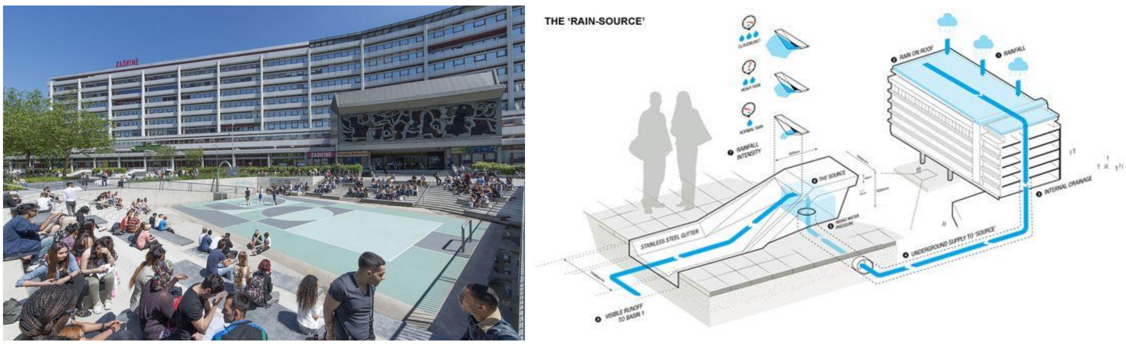


Fig. 11. The Water Square Benthemplein, Rotterdam.

It is worth to note that such project is considered as a grey measure, because it proposes engineering solutions for collecting rainwater during extreme rainfall events, but it involves also green measures, related to the systems of green roofs and green flowerbeds to filter water, as well as soft measures, fostering the active participation of citizens. Therefore, this project increases learning capacity, involving citizens' participation, but also persistence, enhancing robustness through to the collection of rainwater and the control of the water flows; adaptability, by increasing the flexibility and diversity through an articulated rainwater management system that enhance the capacity of the city to cope both with heavy rainfalls and summer heat waves; transformability, thanks to a creative and technically advanced solution to reduce climate impacts.

The Green Roofs Programme is aimed at building up green roofs capable to absorb rainwater and reduce runoff speed as well as the pressure on the sewer system during heavy rainfall. Rotterdam has more than 140,000 m^2 of green roofs on private residential buildings or devoted to tertiary activities, realized through public private funding and financial incentives. The Rotterdam Roof Park – that is part of such programme - represents the largest green roof in Holland: 800 meters long and 80 meters wide, above a commercial building in the neighborhood of Delfshaven in the western area of Rotterdam. The Europe's Largest Green Façade is a project similar to the Rotterdam Roof Park that consists of a green facade in a car park building. The green roofs and facades, besides filtering the water and reduce the overload of rain drains, have also the function to filter the dust particles from the atmosphere to form a buffer against pollution. Thanks to these functions, they contribute to reduce CO_2 emissions, increase biodiversity and reduce the heat island effect in the city center.

Fig. 12. Green Roofs Programme and the Europe's Largest Green Façade, Rotterdam.

Providing the city with green roofs and facades increases adaptability and transformability, by increasing redundancy (a spare capacity due to numerous green roofs and facades that can detain rain water), diversity (different green surfaces can be designed in several urban areas), network capacity and flexibility (the detention of rain water can allow the collection of intense rainwater, by reducing flooding risk). In the absence of rains, these facilities contribute, however, to improve air quality by absorbing CO_2 and to promote a cooling urban environment during heat waves.

The Floating Pavilion is also a pilot project, aimed at building up three transparent floating half-spheres with a radius of 12 m (fig. 13). Such three floating half-spheres are moored in the harbor area called Rijnhaven. The particularity of the Floating Pavilions is that they are climate proof, due to their adaptative capacity to float, according to the rising water levels. The half-spheres are made from a strong, anti-corrosive plastic called ETFE and the internal environmental comfort is guaranteed in each internal zone, through heating and air conditioning systems relying on solar energy and surface water. In such a way, the energy consumptions of the half-spheres are significantly reduced. This is a pilot project that will remain in the Rijnhaven until 2015, then they will be moved in the Stadshavens area. The latter is an area of 1600 hectares that will be planned for Floating Constructions and Communities. Indeed, until 2040, thousands climate change resilient buildings will be built and several hundred will be floating on water, accommodating homes, business and work spaces, as well as recreational spaces.

Fig. 13. Floating Pavilion in Rijnhaven, Rotterdam.

Such project is addressed to increase learning capacity, providing information and data about its suitability in the face of the sea level rising. Moreover, it will enhance the adaptability of the urban system, by increasing diversity and flexibility of the physical subsystem.

In order to reduce air pollution due to the car traffic, the Cleaner Air by means of Dynamic Traffic Management Project - a system able to manage dynamically the vehicular traffic - has been promoted (fig. 14). The system, addressed to timely manage traffic flows thanks to digital information panels alongside roads, allows the reduction of CO_2 emissions by avoiding car congestion.

Fig. 14. Cleaner Air By Means Of Dynamic Traffic Management, Rotterdam

This project increases transformability of the urban system, promoting a transition towards a low-carbon urban mobility and meanwhile supports adaptability by increasing networking capacity, flexibility and connectivity of the transport network, enhancing its capacity to cope with different traffic conditions as well as with different needs of users.

In conclusion, Rotterdam mitigation and adaptation strategies clearly highlight that while soft measures are generally related to social and institutional subsystem and addressed to improve learning capacity, by enhancing networking capacity, monitoring, collaboration and participation, grey and green measures generally refer to all the other subsystems (physical, functional and environmental) and addressed to increase simultaneously persistence, adaptability and transformability. Nevertheless, most of current initiatives in Rotterdam emphasize the need for integrating different types of measures as well as for combining mitigation and adaptation strategies in order to increase urban resilience in the face of climate change.

3 CONCLUSIONS

This study has been focused on the Smart City and Resilient City concepts aiming at developing, based on an integrated approach, operational tools capable to support multi-objective strategies for enhancing cities' capacities to cope with climate change.

The analysis of the two concepts highlights an increasing area of overlap among them and emphasizes that the Smart City is more and more widely interpreted as a place-based process addressed to make cities "more livable and resilient and, hence, able to respond quicker to new challenges" (Kunzmann, 2014) focusing on local peculiarities, issues and priorities.

In order to support such a process and based on current scientific literature, this study has been firstly addressed to identify the main characteristics of a smart and resilient urban system. It has to be underlined that while in the resilience research field a large set of studies and researches have been focused on the characteristics of a resilient system, the Smart City literature does not provide in-depth studies on the characteristics of a smart urban systems. However, some useful hints in this direction have been collected from studies carried out by companies involved in developing Smart City standards (e.g., BIS, 2014) and from researches which investigate Smart City performances and characteristics (e.g., Coe, 2001; Giffinger et al., 2007)

Then, the collected characteristics have been selected and organized into a conceptual model aimed at guiding planners and decision-makers towards the development of multi-objective strategies capable to improve the response capacities of complex urban systems in the face of climate change. In detail, the model sketches phases and times of the process allowing cities to better cope with climate change, underlining roles and linkages of the different characteristics along this process, according to the different time spans (short-medium-long term) that characterize the response of a complex urban system in the face of climate change. The model highlights that some characteristics (adaptability/transformability) are crucial for supporting long-term strategies capable to reduce GHG emissions and energy consumptions; some others (persistence/adaptability) are relevant to short-medium term strategies aimed at reducing the vulnerability of urban systems to the heterogeneous climate-related impacts; others (such as learning) pass through the different time-spans and provide inputs for starting and managing the whole process. Moreover, the model stresses how, although each characteristic comes to the fore in different temporal stages, each of them provide information that, continuously processed, represent an input to further increase the response capacity of the urban system (feedback loop).

Finally, the Rotterdam case study - which has recently adopted a smart strategy, by combining mitigation and adaptation strategies, has been in-depth analyzed in order to understand whether and how strategies and measures undertaken at the city level may contribute to enhance the different characteristics of a smart and resilient urban system.

This study represents a first step along a research path addressed to improve cities capacity to deal with climate related issues, by providing operational tools capable to support integrated strategies for building up smarter and more resilient cities, as well as mitigation and adaptation strategies. Further steps along the presented research path will be related firstly to the enlargement of the sample cases, which might allow reviewing and improving the proposed conceptual model. Then, a crucial step will be related to the development of adequate indicators capable to support decision makers in measuring, qualitatively or quantitatively, the effectiveness of strategies and measures in improving the capacities that make an urban system smarter and more resilient in the face of climate change.

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